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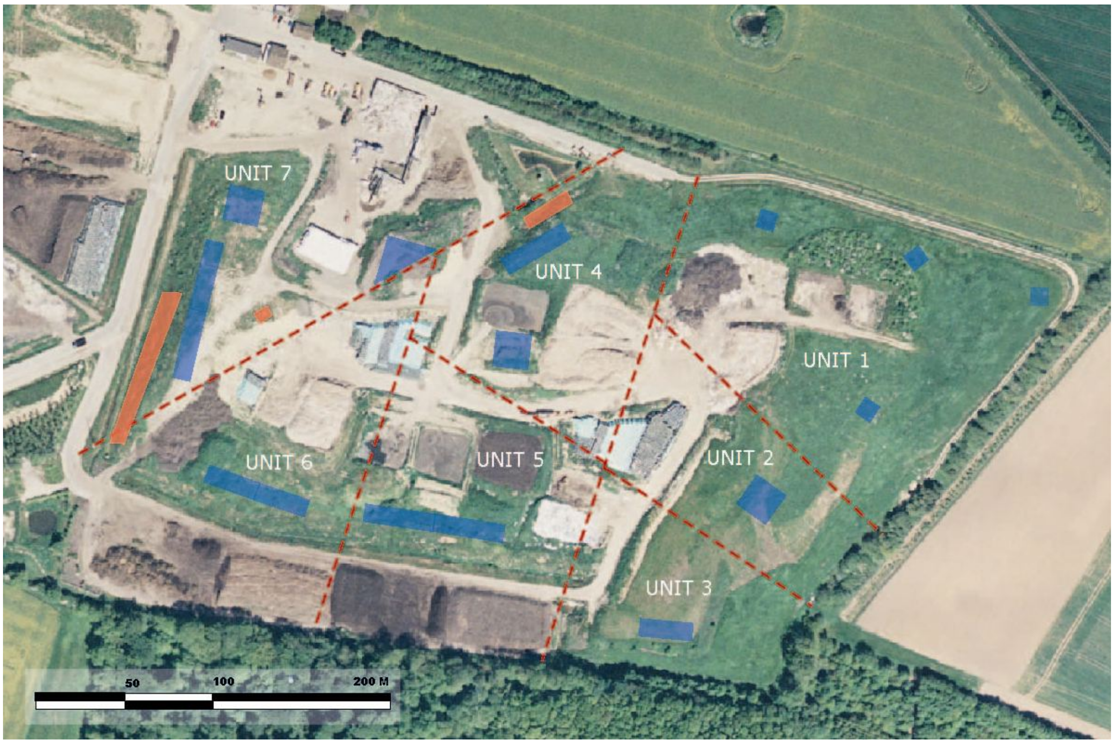

Cover Improvement Plan

Institute of Environment & Resources
Technical University of Denmark

April 2007

BIOCOVER

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Preface

The full title of the BIOCOVER project is *Reduction of Greenhouse Gas Emissions from Landfills by use of Engineered Biocovers*. The project is funded by the LIFE III ENVIRONMENT program, the Danish Environmental Protection Agency, and RENOSAM and runs from August 2005 to November 2008. This report presents the outcome of Action 5.1 *Cover Improvement Plan* (deliverable D.5.1.1) as described in the project application (Biocover, 2005). Fakse Landfill serves as the demonstration landfill for the BIOCOVER project.

Summary

Based on findings of the previous Biocover project tasks, a biocover system is planned for Fakse Landfill taking into account the best estimate of the methane load to the system, methane oxidation capacity of the biocover material, and possibilities of bypass of the system, namely emission through the leachate collection system.

The best estimate of the methane load is the measurements of the total methane emission using continuous tracer release followed by mobile FTIR measurements as described in the report “Whole site methane emissions”. Since the methane load is much higher than anticipated, a total area of the biocover windows of 5000 m^2 is necessary. In all 11 windows of varying sizes are planned and located so that operation of the landfill is not disturbed. Each of the seven disposal units will be equipped with at least one biocover window. Fine compost is chosen as cover material, whereas the root blocking gravel normally used at Fakse landfill will be used as gas distribution layer. The root blocking layer, situated between the compost material and landfilled waste, will have a thickness of 15 cm, whereas the compost material will have a thickness of 100 cm.

A simple gas barrier is designed for prohibiting gas emissions from leachate wells at the site. This system will be installed after the biocover windows are realized. The biocover system will be ready for performance testing August 2007.

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Introduction

Most landfills contain organic wastes which produce biogas, containing methane and carbon dioxide. Emission of methane from landfills is a serious environmental problem and is explicitly mentioned as a source for greenhouse gasses in the EU *Sixth Environmental Action Plan*. In a global perspective, landfills accounts for 7-20% of the anthropogenic methane emissions to the atmosphere.

Landfill gas (LFG) is at some landfills extracted and utilized for energy purposes leading to methane emission reduction. However, it is not always feasible to extract and utilize the landfill gas. In these cases the gas is flared with risk of producing toxic combustion products, or is just escaping to the atmosphere.

A low-cost alternative could be to improve the top covering of the landfill in order to optimize the biological methane oxidation in the cover. Laboratory experiments have documented that a very high methane oxidation rate can be obtained in bio-covers, thereby reducing the methane emission significantly. The biological methane oxidation transforms methane into carbon dioxide, and since methane has a 21 times stronger global warming potential than carbon dioxide, a significant reduction in the source to global warming is obtained. Biocovers may also be a very cost-effective supplementary method at landfills with landfill gas utilization, since the efficiency of the gas extraction system often is in the range of 50-60 %.

The BIOCOVER project has the objective to perform a full scale implementation of engineered bio-covers and to document the methane reduction efficiency. Fakse Landfill in Southern Zealand, Denmark, serves as a demonstration landfill for the implementation of the technology.

Fakse Landfill is divided into two sections. The oldest section which was in use from 1981 until 1997 will be the focus of the project activities. This part of the landfill has an area of 12 hectares and has received mixed waste. Approximately 600,000 tonnes of waste has in total been disposed of at the older part of the landfill. The landfill is typical for Danish landfills of similar age.

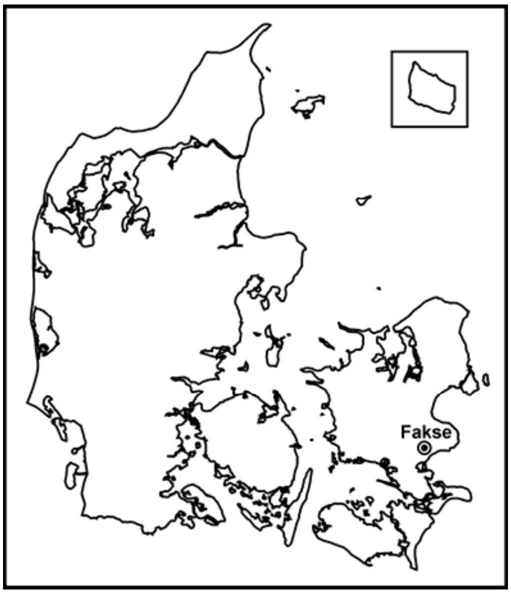

Figure 1. Map of Denmark showing the location of the study landfill, Fakse Landfill

This report concerns the design of the biocover system (Action 5.1) based on the results of previous tasks of the Biocover project: Task 2 “Initial characterization of landfill”, Task 3 “Baseline study of methane emission” and Task 4 “Testing improvement strategies”. The main purpose of this report is to document the final design of the biocover system prior to realizing it at Fakse Landfill.

1 Design parameters

To establish the necessary area of the biocover at the site, two main design parameters are important to establish: Methane load (i.e. amount of methane that flows through the biocover system per day), and methane oxidation capacity of the biocover material (i.e. amount of methane per m^2 biocover material that can be oxidized per day). Results from modeling of the methane production at Fakse Landfill (Lemming & Kjeldsen, 2006) and results of methane emission measurements (Fredenslund et. al, 2006) & (Scheutz et. al, 2007) were used to quantify methane load. Preliminary results from Task 4 “Testing improvement strategies” were used to establish methane oxidation capacity.

Methane load

As part of Task 2 “Initial characterization of Fakse Landfill” landfill gas production models were used to calculate methane production rates for each of the seven disposal units at the site. Table 1 lists calculated methane production rates derived from the results of the gas production modeling (Lemming & Kjeldsen, 2006)

Table 1. Methane production rates determined by use of landfill gas production models (Lemming & Kjeldsen, 2006)

Location	**Range of calculated methane production ($kg\ d^{-1}$)**	**Average of calculated methane production ($kg\ d^{-1}$)**	**Distribution**
Unit 1	37 – 46	42	8 %
Unit 2	36 – 43	40	7 %
Unit 3	29 – 37	33	6 %
Unit 4	77 – 88	83	16 %
Unit 5	75 – 98	87	17 %
Unit 6	61 – 77	70	13 %
Unit 7	137 – 194	166	32 %
Total	485 – 551	518	

Through measurements of local methane emission rates, the total methane emission was assessed to be 533 $kg\ d^{-1}$ (Fredenslund et. al, 2006). This value was established using a tracer release technique (emission through leachate collection and recirculation systems) and flux chamber measurements (emission through soil cover). From this study it was concluded that the methane emission at the time of measurement occurred primarily through the leachate collection system (65 %), while methane emission through the soil cover was focused in emission “hot spots”, which were located on slopes of the low permeable soil cover used at the site. It was also concluded that methane oxidation in the soil cover was negligible at the time of measurement (Fredenslund et. al, 2006).

The total methane emission was measured using two methods (Scheutz et. al, 2007): continuous tracer release followed by downwind plume measurements using a mobile FTIR[1] device and continuous tracer release followed by sampling of downwind plume

[1] Fourier Transform Infrared Spectroscopy

in evacuated gas canisters and analysis of samples using a QCL[2]. Total methane emission from section I measured were 749 kg d^{-1} and 732 kg d^{-1} using the mobile FTIR method on two campaigns (Scheutz et. al, 2007).

Table 2 lists estimated total methane loads calculated using the gas production models described in (Lemming & Kjeldsen, 2006), total methane emission assessed through measurements of local sources (Fredenslund et. al, 2006) and total methane emission measured using FTIR (Scheutz et. al, 2007).

When calculating the total methane load using gas production models, it is assumed that all produced methane flows to the biocover system. Thereby the methane load established using this method is equal to the total production. The same assumption is used when assessing the methane load using emission measurements. All methane measured as emitting from the site at time of measurement is assumed to flow through the biocover system. Also, methane oxidation before installation of biocover system is assumed to be insignificant. Thereby the methane loads derived from emission measurements are equal to the total emission measured in each case.

Table 2. Total methane loads assessed through gas production modeling and methane emission measurements

Method of assessing total methane load on biocover system	Methane load (kg d^{-1})
Calculated methane production using gas production models (average)	518
Local methane emission measurements	533
Total methane emission measurements*	740
Average	597

*Average value of two emission measurement campaigns

The results of each assessment method are quite similar. Results of the total methane measurements were expected to be higher than the sum of the local methane emissions measured, since more diffuse emissions were not quantified in this study. The average load to the biocover system is thus assumed to be closest to the total methane emissions measured using the mobile FTIR.

Methane oxidation capacity

Based on preliminary results of Task 4 “Testing improvement strategies” it was found that the fine compost (shredded raw compost) reaches the highest methane oxidation rate over the first 70 days of the experiment (154 g/m^2/day) followed by Sewage sludge compost (121 g/m^2/day) and Raw Compost 4years (119 g/m^2/day).

Even though fine compost reaches the highest methane oxidation rate of the tested materials, it is not chosen for the biocover windows, since decrease of oxidation efficiency was observed over time during the column experiments. This can be explained by clogging of the pore volume leading to oxygen deficiency. The more coarse materials were seen to be more stable with regards to methane removal, and therefore are to be preferred.

[2] Quantum Cascade Laser

2 Design of biocover system

At Fakse landfill, the final top covering consists of 0.15 meters of root blocking gravel on top of the waste. The gravel is followed by 0.8 meters of raw soil and finally 0.2 meters of top soil (mould) (Lemming & Kjeldsen, 2006).

As originally planed, the thickness of the biocover compost material will be 1 meter. Preliminary results of methane oxidation column experiments (action 4.3) support that this thickness is sufficient. Below the compost material a thinner, coarser inorganic layer of material will be placed. This high permeable layer between the deposited waste and compost will lead the gas from below into the compost material where methane oxidation occurs. The root blocking gravel normally used in the final top cover at Fakse landfill (average grain size = 5 mm) is useful for this purpose, and the same type will be used as gas distribution layer below the compost material in the biocover. A particle size distribution sheet is shown in appendix 1.

Areas and locations of biocover windows

Since the methane emission at Fakse landfill was measured to be much higher than initially anticipated, a much larger area of the biocover is needed compared to the area mentioned in the project proposal (8*160m^2). A total area of 5000 m^2 is necessary, which will result in an average methane load of 150 g CH_4 m^{-2} d^{-1}, according to the measurements of total methane emissions using mobile FTIR, and assuming all methane emitted passes through biocover windows. The anticipated methane oxidation capacity was 150 g CH_4 m^{-2} d^{-1} (Biocover, 2005), and this value is also close to the oxidation capacity measured of the biocover materials (119 to 154 g/m^2/day for over the first 70 days) during testing using column setup.

The distribution of the load to the biocover per disposal unit is assumed to be equal to the distribution of methane production calculated using methane production models. At least one so-called biocover window per disposal unit is considered to be necessary, since the risk of bypass of the biocover system is probable if the windows are too far away from where landfill gas is produced in the waste. Table 3 shows distribution of biocover area and number of windows planned per disposal unit:

Table 3. Distribution of biocover area and number of biocover windows for each disposal unit

	Area of disposal unit (m^2)	**Percentage of total methane production**	**Biocover area (m^2)**	**Number of biocover windows**
Unit 1	22 000	8 %	400	4
Unit 2	11 000	7 %	400	1
Unit 3	11 000	6 %	300	1
Unit 4	14 000	16 %	800	1
Unit 5	17 000	17 %	800	1
Unit 6	22 000	13 %	700	1
Unit 7	24 000	32 %	1600	2
Sum	121 000		5000	11

Figure 4 shows planned locations of biocover windows, as well as areas where the existing soil cover most likely needs to be improved to counter bypass of the biocover windows by the landfill gas. In these areas significant emission of methane was observed using flux box measurements (Fredenslund et. al, 2006). The final location of the biocover windows will be established after a survey of the actual depth of the existing soil cover at each location. An assessment of the emission through the soil cover after constructing the biocover windows will be done, which will be used to more precisely establish where improvement of existing soil cover is necessary. Improvement of the cover will be done by adding more soil (10 to 20 cm) to reduce gas permeability.

Figure 2. Planned locations of biocover windows in blue), and anticipated areas, where existing soil cover needs to be improved

3 Leachate well gas barriers

Since landfill gas produced was proven to emit through the leachate collection system, gas barriers will be installed at most of the leachate collection wells as part of the biocover system. Gas barriers will be installed after the windows are realized.

The gas barriers will be removable PVC caps covering the top of each well. The edges of the caps will be sealed using neoprene rubber seals between the concrete sides of the wells and the caps, and tightening the caps using stainless steel bands. Figure 3 shows a prototype of a gas barrier installed on one of the wells at Fakse landfill. A sketch drawing of the barrier is shown in appendix 2.

Figure 3. Leachate well gas barrier installed on a leachate collection well at Fakse landfill

11 leachate wells will be fitted with gas barriers. Locations of these wells are shown in figure 4.

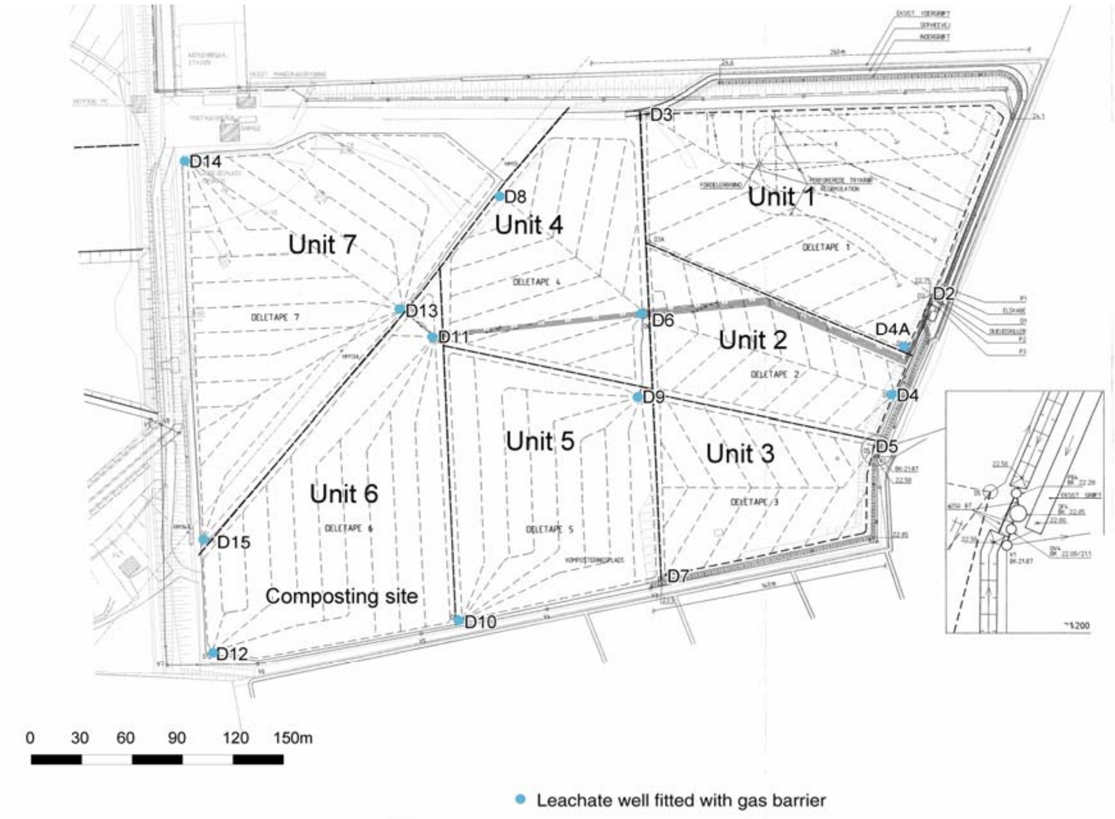

Figure 4. Leachate well gas barriers to be installed at Fakse landfill.

It is chosen not to fit wells D2, D3, D5 and D7 with gas barriers. The emission from these wells was measured to be 5 kg d-1. The total emission of methane through the leachate collection system was measured at 351 kg d-1 (Fredenslund et. al, 2006). D2 and D5 are connected to other installations of the nearby pumping stations, and fitting these wells with gas barriers of the type described is presumed to be ineffective.

4 Time schedule

Overall, the biocover system is scheduled to be ready for performance testing early August, 2007. The Gantt chart below shows the current time schedule for the Biocover project, with details regarding Task 5 “Establishing full scale biocover demonstration system”. The Gantt chart is generated from Microsoft Project 2003, which is used as a management tool of the Biocover project.

One of the 11 biocover windows will be constructed approximately one month before deadline for completion of all biocover windows, in order to test equipment for measurement of biocover performance.

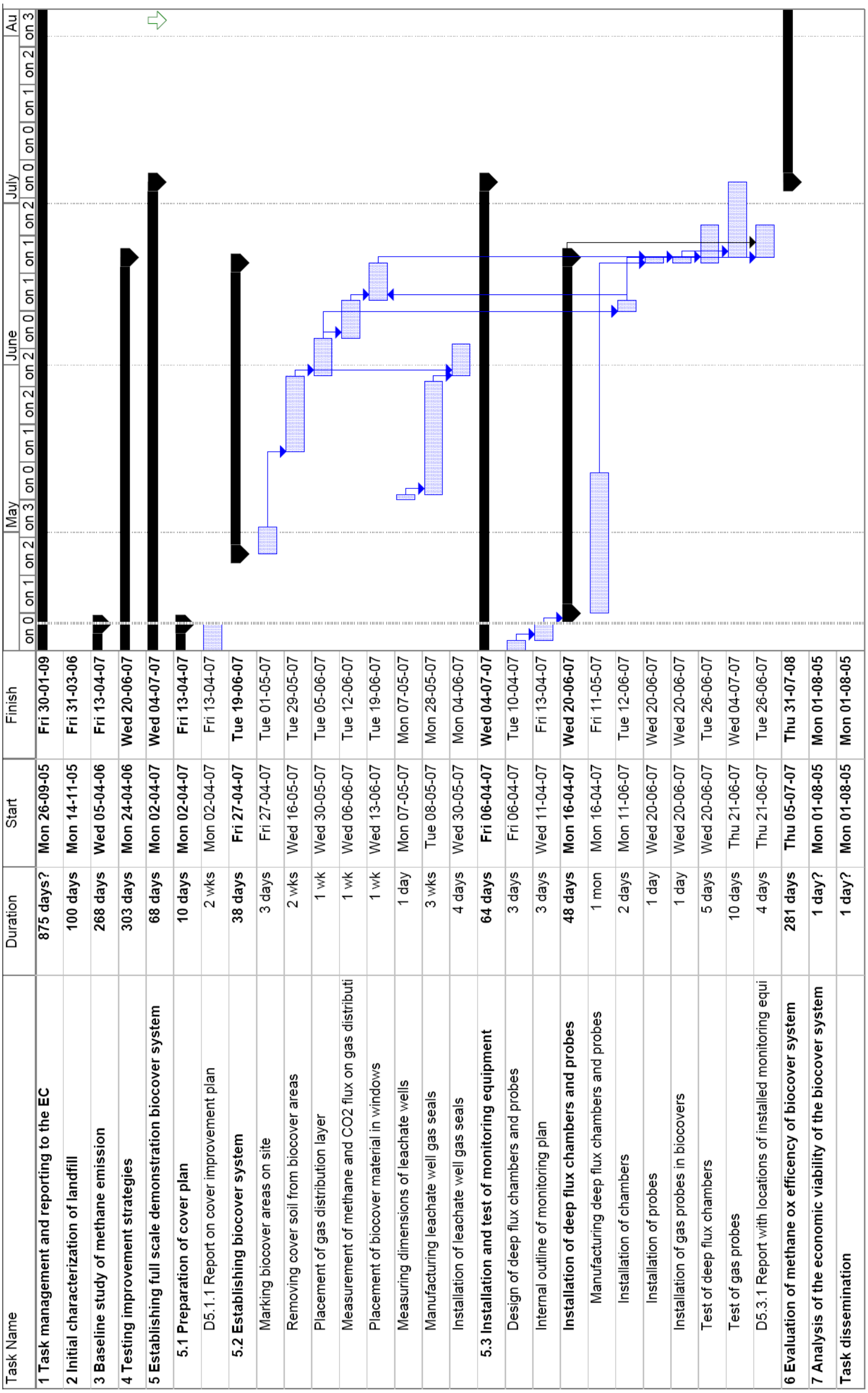

Figure 2. Gantt chart of Biocover project including sub tasks of Task 5: “Establishing full scale demonstration biocover system

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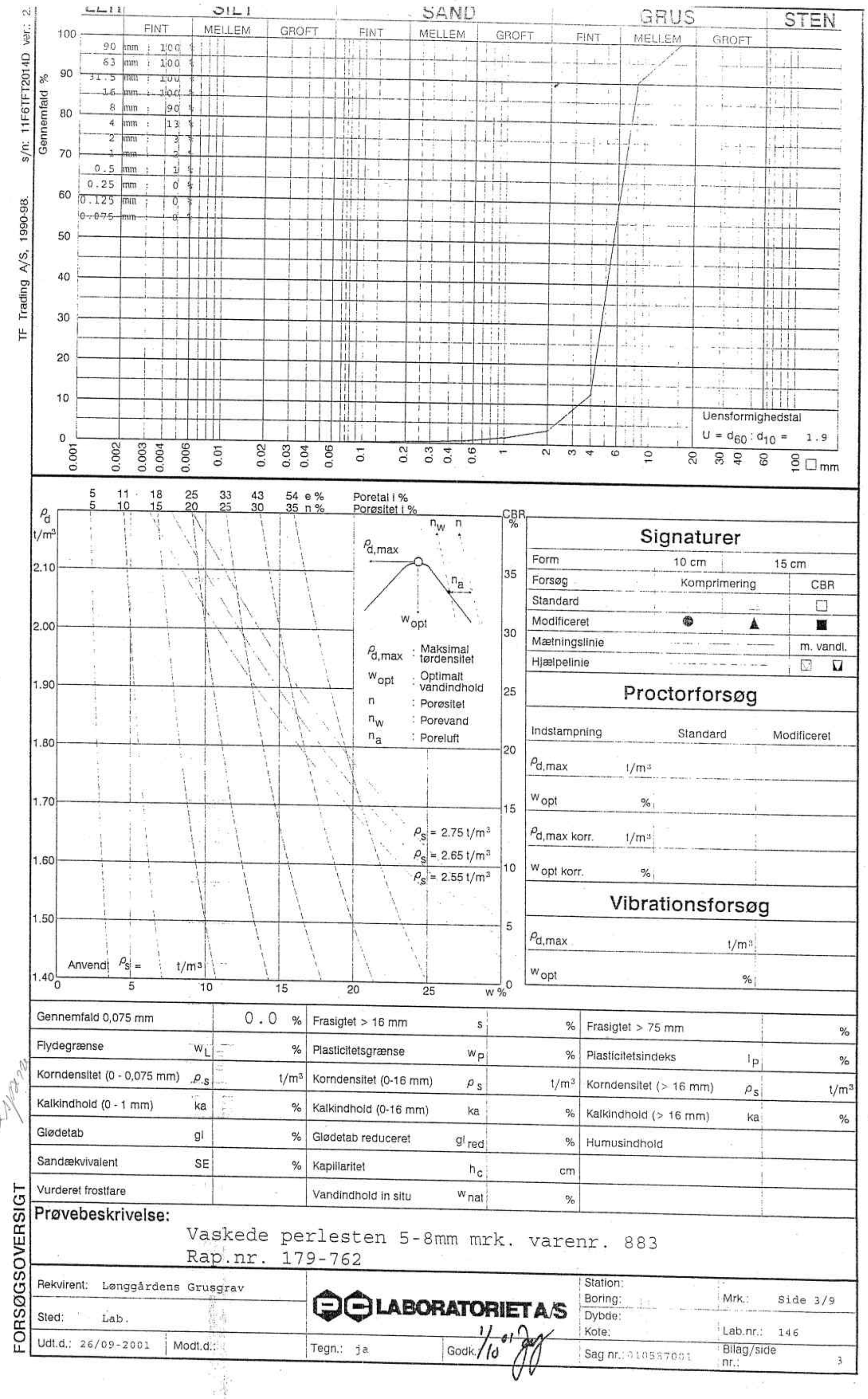
Scheutz, C., Fredenslund, A.M., Samuelsson, J., Jacobs, J., Scharff, H., Kjeldsen, P. (2007) Whole landfill methane emission. Biocover project report D.3.2.1b

Appendix 1

Particle size distribution of root blocking gravel used as part of soil cover at Fakse Landfill.



90 mm	:	100 %
63 mm	:	100 %
31.5 mm	:	100 %
16 mm	:	100 %
8 mm	:	90 %
4 mm	:	13 %
2 mm	:	3 %
1 mm	:	2 %
0.5 mm	:	1 %
0.25 mm	:	0 %
0.125 mm	:	0 %
0.075 mm	:	0 %

Uensformighedstal $U = d_{60} : d_{10} =$ 1.9

Gennemfald 0,075 mm		0.0	%	Frasigtet > 16 mm	s		%	Frasigtet > 75 mm			%
Flydegrænse	w_L		%	Plasticitetsgrænse	w_P		%	Plasticitetsindeks	I_P		%
Korndensitet (0 - 0,075 mm)	ρ_s		t/m³	Korndensitet (0-16 mm)	ρ_s		t/m³	Korndensitet (> 16 mm)	ρ_s		t/m³
Kalkindhold (0 - 1 mm)	ka		%	Kalkindhold (0-16 mm)	ka		%	Kalkindhold (> 16 mm)	ka		%
Glødetab	gl		%	Glødetab reduceret	gl_{red}		%	Humusindhold			
Sandækvivalent	SE		%	Kapillaritet	h_c		cm				
Vurderet frostfare				Vandindhold in situ	w_{nat}		%				

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Rap.nr. 179-762

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Appendix 2

Sketch drawing of leachate well gas barrier